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Air Force Office of Scientific Research Grant # F49620-92-J-0223
Development of Function-Based Modeling for Generic Recognition
Progress Report for 1/August/1994 through 31/July/1995

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This report for the research grant F49620-92-J-0223, titled *Development of function-based modeling for generic object recognition*, covers the period 1 August 1994 through 31 July 1995. This report provides a summary of the major areas of activity and the current results in each area, a list of the Ph.D. candidates working on the different areas of the project and a list of publications. Copies of recent publications from *Transactions on PAMI* and the 1995 *IEEE Symposium on Computer Vision* are attached.

1 Major areas of activity

1.1 Use of partial shape models

Complete shape information about an unknown object is generally not available in an observer's first view of the object. For this reason, we have been working on the extraction of partial shape models from an initial view of an object. We have given the name "OPUS" (Object Plus Unseen Space) to the type of shape model that we construct from an initial view of a 3-D object. The results of our initial work on function-based recognition from OPUS shape models have been evaluated using a database of over 200 real laser range finder images. Out of concerns for generality and robustness, we are evaluating the algorithm for OPUS construction with range data from a structured light scanner as well as data from the time-of-flight laser range finder. This line of work is being extended to include incremental construction of OPUS models from multiple views and the development of function-driven strategies for selection of a sequence of views. Portions of this work have been accepted for publication in *Transactions on Pattern Analysis and Machine Intelligence*.

1.2 Application of machine learning techniques

The application of machine learning techniques to computer vision systems has recently begun to receive increased attention in the community. In the GRUFF project, we have been looking at possible ways to simplify the problem of extending the domain of competence to include new object categories. At the moment, this involves a fair amount of handcrafting of various parameters for the knowledge base that describes the function appropriate to the object category. In particular, for each *knowledge primitive* invocation in the system, there can be four values which defined the evaluation measure for the invocation. (In other words, at each place that

an observation about width, depth, area, relative orientation or such is made, there are four values to be given to specify the range of appropriate values.) We have developed a machine learning technique to automatically derive an appropriate set of values from a small set of labeled examples. This work has been accepted for publication in the *Journal of Artificial Intelligence Research*.

1.3 Extensions to the domain of articulated objects

We are working on the extension of the domain of competence of the GRUFF system to include objects composed of rigid parts with articulated connections between them. While the current version of GRUFF can handle objects such as "hammer" and "screwdriver", we are aiming at a version which would also handle objects such as "pliers", "scissors", "adjustable wrench" and "hand drill". A description of the early results of this work has been accepted for publication in *Computer Vision and Image Understanding* (formerly titled *CVGIP: Image Understanding*). Implementation and evaluation of this system is continuing.

1.4 General publications

In addition to the above-listed research topics and publications, Louise Stark has served as guest editor of a special issue of *Computer Vision and Image Understanding*, tentatively scheduled for September 1995 publication, devoted to the role of functionality in object recognition and Professors Stark and Bowyer are preparing a monograph on the Gruff project to be published by World Scientific Publishing Company.

2 Ph.D. candidates working on the project

2.1 Melanie Sutton

Ms. Melanie Sutton is currently in her second year in the graduate program at USF. She has contributed to several stages of the generalization of the basic GRUFF system. She was the primary contributor in adding the example domain of the superordinate category "dishes" to the system. She has also been collaborating on other areas of the project.

2.2 Adam Hoover

Mr. Adam Hoover is currently in his second year in the graduate program at USF. He has been working primarily in the area of extending the GRUFF system to reason about input shape descriptions of the type acquired from a real mobile robot and laser range finder. He has also been collaborating on other areas of the project.

2.3 Kevin Green

Mr. Kevin Green is currently in his fourth year in the graduate program at USF. He has been working out the conceptual extensions necessary to extend the domain of objects that can be handled to include articulated objects; that is, objects with moving parts. Simple examples would be scissors, pliers and adjustable wrenches.

3 List of Publications For This Year of the Project

- K. Woods, D. Cook, L. Hall, L. Stark, and K. Bowyer. Learning Membership Functions in a Function-Based Object Recognition System accepted to appear in *Journal of Artificial Intelligence Research*.
- Hoover, A.W., Goldgof, D.B. and Bowyer, K.W. Extracting a Valid Boundary Representation from a Segmented Range Image, accepted to appear in *IEEE Transactions on Pattern Analysis and Machine Intelligence*.
- Green, K., Eggert, D., Stark, L. and Bowyer, K.W. Generic recognition of articulated objects through reasoning about potential function, accepted to appear in *Computer Vision and Image Understanding*.
- Sutton, M., Stark, L. and Bowyer, K. GRUFF-3: Generalizing the domain of a function-based recognition system, *Pattern Recognition* 27 (12), 1743-1766, December 1994.
- Stark, L., Bowyer, K.W., Woods, K., Hall, L., and Cook, D. Application of learning techniques in a function-based recognition system, to appear in Symbolic Visual Learning K. Ikeuchi and M Veloso, editors, Oxford University Press, 1995.
- Hoover, A., Jean-Baptiste, G., Jiang, X., Flynn, P.J., Bunke, H. and Bowyer, K. Range image segmentation: the user's dilemma, *1995 IEEE International Symposium on Computer Vision*, Miami, Florida (November 1995).
- Sanocki, T., Bowyer, K. Adair, J., and Sarkar, S. Are real edges sufficient for object recognition?, Full version submitted for journal review, early version presented at *Annual Meeting of Association for Research in Vision and Ophthalmology*, Palm Beach, Florida (May 1995).